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16. Abstract

The objective of the study was to evaluate the cost-effectiveness of available marking materials by means of field tests and to make recommendations concerning the optimum lane delineation materials based on these tests. Materials tested include 100-percent solid epoxy paint, polyester paint, extruded thermoplastic, 3M Stamark tape, 3M Bisymmetric tape, EPOFLEX, solvent epoxy paint, chlorinated rubber traffic paint, and alkyd traffic paint. The test installations have been in place up to four years. The evaluation concerned the durability, reflectivity, and appearance of the materials.

Based on current data, expanded use is warranted for 1) polyester paint on lower-volume asphaltic concrete surfaces, 2) extruded thermoplastic on higher-volume asphaltic concrete highways with lighting or snowplowable markers, and 3) extruded thermoplastic on open-graded asphaltic surfaces.

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Research Report
UKTRP-86-15

# EVALUATION OF DURABLE LANE DELINEATION MATERIALS

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and

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EVALUATION OF DURABLE LANE DELINEATION MATERIALS

## EXECUTIVE SUMMARY


Traffic paints, typically alkyd formulations, have been used as lane delineation on Kentucky highways for decades. In the past few years, more durable marking materials have been developed. The objective of this study was to evaluate the cost-effectiveness of available durable marking materials by means of field tests and to make recommendations concerning the optimum lane delineation materials based on these tests.

Various types of materials to be evaluated were placed under several contracts. All but two of the test sections were placed in Kentucky and the other two were in Indiana. Following is a list of the nine materials included in the analysis:

1. 100-percent solid epoxy paint
2. Polyester paint
3. Extruded thermoplastic
4. 3M Stamark tape
5. 3M bisymmetric tape
6. EPOFLEX
7. Solvent epoxy paint
8. Chlorinated rubber traffic paint
9. Alkyd traffic paint

Data collecton included three areas: 1) durability, 2) reflectivity, and 3) appearance. The method of conducting road service tests as described in ANSI/ASTM D 713-69 was used as a guide. It describes the rating of traffic paint in terms of appearance, durability, and nighttime visibility. Both daytime and nighttime photographs were taken to document the durability, reflectivity, and appearance evaluations.

Based on current data, expanded use is warranted for 1) polyester paint on lower-volume asphaltic concrete surfaces, 2) extruded thermoplastic on higher-volume asphaltic concrete surfaces havng lighting or snowplowable markers, and 3) extruded thermoplastic on open-graded asphaltic concrete. A very high percentage of state-maintained highways have low traffic volumes, therefore, polyester paint could be used. Almost 80 percent of the total mileage included on the statewide roadway volume file has an ADT under 2,500. Over 90 percent of Kentucky's highways are surfaced with bituminous concrete. The use of portleand cement concrete pavement increases dramatically for routes having ADT's exceeding 10,000. These higher-volume roadways are where extruded thermoplastic would be cost-effective, so the effectiveness of thermoplastics on portland cement concrete pavements should receive further investigation.

The high cost of tapes, expecially Stamark-type tapes, precludes widespread use. Furthermore, the Stamark tape could be used only where the roadway is lighted or has snowplowable markers in place. No further use of the 100-percent solid epoxy, EPOFLEX, or solvent epoxy paint is recommended until such time that additional testing proves problems have been resolved.

## INTRODUCTION

Traffic paints, typically alkyd formulations, have been used as lane delineation on Kentucky highways for decades. In the past few years, more durable marking materials have been developed. These include epoxy and polyester paints, preformed tapes, and thermoplastics. These materials could prove to be more cost-effective than typical traffic paint on certain types of highways. There is a need to field test the various materials and evaluate their performances. Based on field performances and the costs of the materials, a plan detailing where certain materials should be used could be developed.

The objective of this study was to evaluate the cost-effectiveness of available durable marking materials by means of field tests and to make recommendations concerning the optimum lane delineation materials based on these tests. Some test installations have been in place for almost four years.

## INSTALLATIONS

Various types of materials to be evaluated were placed under several contracts. All but two of the test sections were placed in Kentucky and the other two were in Indiana. Following are a list and brief description of the nine materials included in the analysis:

1. 100-percent solid epoxy paint

This material is a two-component, chemically-reacted system that is 100 percent solids. The two parts are mixed by pumps on the striping equipment. The existing stripe was removed prior to placing the epoxy. Line thickness was 15 mils wet and dry. A no-track time of 10 minutes was specified and cones were used for protection. Beads were applied at about 23 pounds per gallon for reflectivity and as a means to prevent tracking. Two types of epoxy paints were used. They were manufactured by Polycarb and Prismo.

2. Polyster paint

This material is a two-component, thermosetting material consisting of a resin and a catalyst. Two separate systems and guns are required on the striper. A minimum thickness of 16 mils was specified. The wet and dry thicknesses would be approximately the same. A pressure-regulated air jet was used to remove all debris from the pavement in advance of the spray guns. Glass beads were applied by pressure at a rate of 15 pounds per gallon. Air temperature had to be above 40 degrees Fahrenheit. No-track time is 8 to 12 minutes on a normal sunny day; therefore, line protection is required. Two types of polyester paints were used. They were manufactured by Glidden-Durkee and Baltimore Paint.

3. Extruded thermoplastic

Hot-applied thermoplastics are thick pavement marking materials consisting of resin binder, reflective glass beads, coloring agents, and inorganic filler. The extruded thermoplastic was placed at a thickness of 90 mils using a die. A maximum drying time of 15 minutes was specified. The thermoplastic material was manufactured by Pave-Mark. The original installations, placed at narrow bridge locations, used a hydrocarbon-resin material while two more recent small test installations used an alkyd-resin material.

4. 3M Stamark tape

This is a preformed tape or a retroreflective film consisting of plastic material, pigments, and glass beads. It is manufactured by 3M. Beads are distributed throughout the film and form a layer bonded on the surface. The thickness is 60 mils. Tape was overlayed on existing pavements. According to the manufacturer, this tape is a highly durable, conformable, and moderately reflective marking designed for use as words and symbols, lane lines, edge lines, and channelizing lines on newly resurfaced roads.

5. 3M bisymmetric tape

This is a preformed tape having a metal-foil backing, a pigmented surface layer, and 1.75 refractive index glass beads. It is manufactured by 3M. Thickness is about 25 mils. Tape was overlayed on existing pavements. According to the manufacturer, this tape is a highly reflective and moderately durable marking material designed primarily for use on streets having lower traffic volumes and free rolling traffic.

6. EPOFLEX

This is an epoxy thermoplastic material consisting of a binder, pigment, a calcium carbonate filler, and premixed glass beads. The material is sprayed at a temperature not to exceed 460 degrees Fahrenheit and at a thickness of 20 mils, which is also the dry-film thickness. Beads are applied at a rate of about 4 to 6 pounds per gallon dropped on and 2 pounds per gallon mixed, giving a total of 6 to 8 pounds per gallon. No coning is necessary since no-track time is less than five seconds. The EPOFLEX was manufactured by Pave-Mark.

7. Solvent epoxy paint

Epoxy paints use two-component epoxy mixed with a reaction-blocking solvent. In the presence of solvent, the mixture remains liquid up to 10 days. When sprayed at 15 mils wet, it dries to about 10 mils. About 6 pounds of pressure-applied beads per gallon of paint are typically used. At a temperature of 75 degrees Fahrenheit, it has a no-track time of 3 to 5 minutes. Solvent epoxy paints manufactured by Saf-T-Mark, Prismo, and Polycarb were used.

8. Chlorinated rubber traffic paint

This typical traffic paint includes the paint binder and solvent as well as pigment and glass beads. The paint is applied at 15 mils wet, which dries to about 8 mils. Pressure-applied beads are applied at a rate of 4 pounds per gallon of paint. Chlorinated-rubber resins were used. The paint was manufactured by Ennis Paint Company.

9. Alkyd traffic paint

This is another typical traffic paint, as the chlorinated rubber paint, which includes the paint binder and solvent as well as pigment and beads. The paint is applied at 15 mils wet, which dries to about 8 mils. Pressure-applied beads are applied at a rate of 4 pounds per gallon of paint. Alkyd resins were used. The paint was manufactured by DeSantis Coatings Incorporated.

## DATA COLLECTION

Data collection included three areas: 1) durability, 2) reflectivity, and 3) appearance. The method of conducting road service tests as described in ANSI/ASTM D 713-69 was used as a guide. It describes the rating of traffic paint in terms of appearance, durability, and nighttime visibility. Both daytime and nighttime photographs were taken to document the durability, reflectivity, and appearance evaluations.

Durability and appearance of the various materials were evaluated visually. The durability evaluation related to the ability of the material to remain on the surface. The appearance evaluation dealt with color of the white or yellow lines as compared to their original color and as compared to a desirable color. Reflectivity readings were measured using a portable retroreflectometer (PRR). Nighttime observations were also conducted.

## RESULTS

Following is a discussion of the results of the evaluations, individually, for the various marking materials. Typical prices, in terms of installed cost per linear foot of a 4-inch line, for the various materials are given in Table 1. These prices were based upon discussions with various highway agency officials and company representatives as well as data contained in the literature. A summary of the portable retroreflectometer (PRR) data is given in Table 2. Measurements are presented by year. The measurements were taken several times during the year (except in 1986 when only one measurement was obtained) and averaged.

### 100-PERCENT SOLID EPOXY PAINT

Four separate installations involving solid epoxy paint were placed in the summer of 1982 by three separate contractors. Three of the contracts involved lane marking on state-maintained streets in three major metropolitan areas: Fayette County, Jefferson County, and the northern Kentucky counties of Boone, Kenton, and Campbell. The other contract involved pavement markings at various narrow bridge locations throughout the eastern portion of Kentucky.

Over seven million linear feet of solid epoxy paint were applied under the four contracts. The contract cost varied from 24.3 to 25.6 cents per linear foot. These prices were midway of the typical price range of 20 to 30 cents per linear foot. The contract specified that at least 65 percent of the pavement be exposed prior to application, which required removing the old painted line. The old line was typically ground off as shown in Figure 1. The pavement condition before paint application is shown in Figure 2. On the Lexington project, an effort was made to remove all existing paint, resulting in the removal of some pavement. The epoxy line was therefore placed slightly below the top of the pavement (Figure 3), which had an adverse effect when moisture was present.

As previously noted, a large quantity of beads were placed on the stripe. That reduced the no-track time and also increased reflectivity. Beads were applied using either a free-fall dispenser (Figure 4) or by pressure through bead guns (Figure 5).

As shown by PRR measurements in Table 2, the initial reflectivity was good compared to the other materials and was maintained as well as any other material in areas where durability was not a problem. Shown in Figures 6, 7, and 8 are nighttime photographs of the same section of roadway in 1982, 1984, and 1986, respectively. After approximately four years in service, the reflectivity remained fairly adequate. This was revealed through nighttime observation and PRR measurements. However, all but a few locations were restriped with traffic paint after approximately three years in service due to durability problems.

The nighttime photographs shown in Figures 6, 7, and 8 show areas in which durability problems did not exist. However, varying levels of durability problems were experienced on each of the four solid epoxy contracts. All problems were attributed to improper mixing of the two epoxy components. The problem was related to not controling pressure on the pumps on the striping equipment. The problem was first noticed and documented as being serious in the northern Kentucky area. As shown in Figure 9, the first evidence of a problem was a brown discoloration of the stripe. This discoloration appeared at a regular interval along the stripe, which corresponded to the cycle of the pump that was not properly proportioning the two components. Spots became darker, as shown in Figure 10, as the material softened. Eventually, the dark (soft) portion of the line wore off (Figure 11). Daytime and nighttime photographs of one roadway section that experienced this problem are shown in Figures 12 and 13. The sensitive nature of this problem may be seen in that two solid yellow lines were placed side by side, and one line experienced the durability problem while the other did not. An extreme example of the problem is shown in Figures 14 and 15, which show striping a few weeks and about two years after placement, respectively.

A 90-day proving period was specified in the contracts. Any 2,000-foot section that experienced more than 10 percent failure was to be replaced. The only replacement required was part of the northern Kentucky installation, although durability problems were observed on the Jefferson County project during the 90-day proving period. Several miles of epoxy lines were replaced in northern Kentucky in 1983. One problem observed at some of the replacement locations was a lake of bond between the new and old stripe. This was probably related to poor adhesion of the remaining old stripe to the pavement. After a couple of years, the replaced lines showed the same durability problems as the original lines. The replaced lines were then painted over at the same time as the lines.

Stripes placed as part of the Fayette County project presented less severe problems initially. No problems were detected during the 90-day proving period and no significant problem was noted during the first year. Inspections after two years of service indicated some sections were developing discolorations, which was evident much earlier in the other projects. After almost three years in service, the durability problems increased to the point that the lines were painted over.

Problems also were observed in the appearance of the solid epoxy lines, specifically the white lines. The daytime appearance of the markings was good immediately after placement, as shown in Figure 16. The yellow line generally retained a good appearance (Figure 17). However, the yellow was not as bright as that provided by typical traffic paint. Also, the white line was not as bright as typical traffic paint and had a dull or gray appearance. The grayish color of the white line was more of a problem on portland cement concrete (as shown in Figure 18) where the color of the line blended with the pavement surface.

POLYESTER PAINT

Polyester paint was first used in Jefferson County in the summer of 1982 with a project completed at a contract price of 7.4 cents per linear foot. This price was the lowest of any of the durable materials. Under the same contract, in 1983, 1984, and 1985, resurfaced roads were striped and most of the original roads were restriped. Up to three layers were placed at some locations. The striping equipment used is shown in Figure 19.

PRR measurements and nightime observations showed the white material maintained its reflectivity better than the yellow. The yellow stripes were subject to more wear since they were used as centerline while the white material was used as edge line. Nighttime photographs taken in 1982 and 1986 of one section of roadway striped with polyster paint are shown in Figure 20 and 21, respectively. The edge line has not been restriped while the centerline was restriped in 1983. The PRR measurements have showed slight increases in some time periods compared to previous years, this was the result of additional paint applications.

No significant durability problems were experienced when the polyester paint was placed over pavement or old paint. Shown in Figure 22 is a new installation. The same location almost four years later is shown in Figure 23 (it had been restriped in 1983 and 1985). The only durability problems noted were at some loations where new polyester was placed over old polyester paint. The new paint did not adhere well to the old paint (Figure 24). This was related to a formulation problem, which was resolved in later restriping installations.

While polyester paint generally did not appear as bright in color as typical white or yellow traffic paint, its daytime appearance was adequate. Again, the only appearance problem was related to the formulation used when restriping over old polyester. When the formulation was originally changed, solvent was added so it would dry quicker and would not chip as previously shown in Figure 24. This problem was solved, but the paint remained tacky, allowing it to become contaminated with dirt, resulting in off-color lines as shown in Figure 25. This problem was solved by using another formulation from a different paint manufacturer.

Most markings were placed on low-volume streets; therefore, performance on high-volume streets is unknown. Also, all materials were placed on asphaltic concrete since work conducted in other states revealed durability problems when polyester paint was placed on portland cement concrete.

EXTRUDED THERMOPLASTIC

One project involving hydrocarbon-resin extruded thermoplastic was completed in the summer of 1982. The project involved pavement markings at narrow bridge locations throughout the western portion of the state. Slightly over one million linear feet of centerline and edge line were placed at a cost of 47 cents per linear foot. The unit price was high due to excessive travel necessary between various bridge locations. A more typical price would be 25 to 35 cents per linear foot, as noted in Table 1. As shown in Figure 26, the material was extruded through a die and then beads were sprayed onto the material. Two additional small sections of alkyd-resin extruded thermoplastic were placed in Lexington in the spring of 1985 using the small striping apparatus shown in Figure 27.

As shown in Table 2, for the 1982 installation, the white lines have maintained reflectivity fairly well while yellow lines suffered an early significant loss in reflectivity. The increase in PRR readings for the yellow lines may have resulted from exposing some of the beads that were embedded in the material. The loss in reflectivity is seen in Figures 28 and 29, which show the same bridge location a few months and about two years after placement of the markings. The white edge line on the right in Figure 29 has been covered with patching material. Loss of reflectivity of the yellow line may be partially explained by Figure 30. As shown in that figure, the surface of the line contains numerous small holes. The holes may have resulted either from placing the material at an excessive temperature, which allowed surface beads to sink into the material, or from moisture on the pavement at the time of installation.

The durability of the 1982 installations has been good. Almost all of the material was placed on bituminous pavements because of the previously reported durability problem on portland cement concrete that is illustrated in Figure 31. An installation on a bituminous surface approximately three years after placement is shown in Figure 32. This shows the good durability and appearance of the installations. The lines have maintained their original color and appearance quite well. The small holes in the surface of the yellow line do not adversely affect appearance when viewed from a distance of over a few feet.

Photographs showing the daytime appearance of one of the alkyd-resin extruded thermoplastic test sections immediately and about one year after placement are included in Figures 33 and 34, respectively. The durability and appearance of the lines have been maintained well. Nighttime photographs of this material are shown in Figures 35 and 36. The PRR data included in Table 2 show high initial reflectivity measurements for the alkyd-resin thermoplastic, which would be related to the amount of surface beads applied. The data, along with the photographs, show that reflectivity has been maintained very well after a one-year period. This material was placed on both bituminous and portland cement concrete pavements. A primer was applied to the pavement before application on the concrete pavement. No durability problems have been noted on the bituminous pavement; but, as shown in Figure 37, some durabilitly problems have been experienced on the portland cement concrete pavement. The problem appears to be related to a loss of bond between the material and the pavement.

## 3M STAMARK TAPE

A project involving 3M Stamark tape as lane delineation was completed in Jefferson County in the summer of 1982. The contract unit price per linear foot was \$0.98 for yellow and \$1.10 for white 4-inch lines. That was the most expensive of all materials evaluated. The tape was placed using equipment shown in Figure 38.

PRR measurements presented in Table 2 show that the Stamark tape had a very high initial reflectivity, but that level of reflectivity was not maintained. Nighttime photographs, Figures 39 and 40, show the tape a few weeks and approximately two years after placement, respectively. The photographs were taken at the same location. Shown in Figure 41 is a roadway on which both Stamark tape and polyester paint were used. The superior reflectivity of the white polyester paint is evident.

There were no problems with durability or appearance of the Stamark tape. As may be seen in Figure 42, after four years in service, the lines have remained intact and maintained their color. While the stripe shown in Figure 42 provides a good daytime line, it does not provide nighttime delineation, as shown in Figure 40.

### 3M BISYMMETRIC TAPE

This tape was placed as a lane line along a few blocks of one street in Lexington in September 1982. The street has an ADT of slightly over 20,000. A typical price per linear foot of 4-inch stripe would be in the range of 50 to 60 cents.

PRR measurements indicated this tape had the highest initial reflectivity of any material, as illustrated in the nighttime photograph in Figure 43. After one year, its reflectivity was still high, but it dropped dramatically after the second year (Figure 44) to approximately the level of the Stamark tape. The roadways were restriped after the tape had been in service for about two years.

The durability and appearance of this tape were satisfactory. A photograph of the tape approximately two years after placement is shown in Figure 45. The tape was placed on both portland cement concrete and asphaltic concrete and exhibited good durability on both.

### EPOFLEX

In October 1985, a test section of a revised epoxy thermoplastic (EPOFLEX) material was placed on the Jefferson Freeway in Jefferson County. The equipment used in the installation is shown in Figure 46. However, this material has been used in several states in the past few years and initial inspections were made of installations in Indiana. In the summer of 1983, Indiana awarded contracts totaling over one million linear feet at costs ranging from 14 to 17 cents per linear foot in three highway districts. PRR measurements were obtained in 1983 and then one year later. Reflectivity of this material, especially the yellow, was not as high initially as other materials. Measurements after about one year in service showed that the reflectivity had been reduced to low levels. Significant durability problems were experienced after less than one year in service. A photograph taken after about one year in service (Figure 47) shows the loss of material.

Failures similar to those observed in the inspection in Indiana were noted in other states. Changes in the EPOFLEX formulation were then made. The test section placed on the Jefferson Freeway was part of Federal Highway

Administration Demonstration Project No. 60 to evaluate the EPOFLEX material. Daytime and nighttime photographs of the test installation after a few days in service are shown in Figures 48 and 49, respectively. The material was placed on portland cement concrete pavement. After six months in service, no major failure was noted. However, durability problems (as shown in Figure 50) have been observed. The durability problem appears to be related to a failure in adhesion between the EPOFLEX and the pavement. An estimate was made that approximately 20 percent of the material had been lost after the initial six-month period. The appearance compared well to regular traffic paint. Initial reflectivity was similar to that of regular traffic paint, which is logical since a similar amount of beads were dropped on, and the reflectivity was maintained over this six-month period. The evaluation will continue as part of the Demonstration Project.

## SOLVENT EPOXY

This marking material has been used in several states, but not in Kentucky. As with EPOFLEX, an inspection was made of an installation in Indiana. In the summer of 1983, three projects, involving about 1.7 million linear feet of this material, were completed at a cost ranging from about 9 to 13 cents per linear foot.

PRR measurements taken a few weeks after placement indicated very low reflectivity. A close visual inspection revealed the beads were originally embedded properly but had been lost. The bead pockets were clearly visible. No additional inspections were conducted because of bead retention failure.

## CHLORINATED RUBBER TRAFFIC PAINT

The Kentucky Department of Highways used a chlorinated-rubber based traffic paint for the 1982 striping season and that was included in the evaluation. Placement of this stripe is shown in Figure 51. Beads were applied under pressure at a rate of about 4 pounds per gallon. The bead gun was aimed so that paint and beads hit the pavement surface at about the same time. That procedure was used to obtain proper bead embedment.

PRR measurements indicated the initial reflectivity was relatively high but had decreased dramatically after about one year in service. Nighttime photographs, Figures 52 and 53, show lines a few months and about one year after placement, respectively. Test sections were restriped after one year in service, so no additional data were available. No durability or appearance problems were experienced during the one-year period.

## ALKYD TRAFFIC PAINT

An alkyd traffic paint was used by the Kentucky Department of Highways for the 1985 striping season and was also included in the evaluation. Placement was the same as shown in Figure 51 for the chlorinated rubber paint.

PRR measurements at several locations in Lexington indicated the initial reflectivity to be below that recorded for the chlorinated rubber but, after one year, measurements had decreased to a similar level. The sections were restriped after about one year in service. No durability or appearance problems were experienced during the one-year period.

# SUMMARY AND CONCLUSIONS

## 100-PERCENT SOLID EPOXY PAINT

This material had the highest reflectivity of any of the paints. However, durability and appearance problems preclude widespread future use until it is demonstrated that those problems have been solved. The durability problem was related to equipment problems, specifically improper mixing of the two epoxy components. The major appearance problem was the dull daytime appearance of the line. This material had been used extensively in other states, and the manufacturer of the paint indicated that the two problems have been remedied and the material has been used successfully in other states. Another test installation is warranted to determine whether future use of the material is justified.

## POLYESTER PAINT

Polyester paint had the lowest price of any of the durable materials. Reflectivity was adequate, although not as good as solid epoxy. Some durability and appearance problems were detected but were solved by changing the paint formulation. Future use of this material is warranted on low-volume asphaltic concrete pavements. Additional testing is needed to determine whether this material may be used on high-volume roadways. Also, since there has been restriping in 1983, 1984, and 1985 at the Jefferson County locations, there is a need for continued monitoring.

## HYDROCARBON-RESIN EXTRUDED THERMOPLASTIC

Initial reflectivity was high, but considerable loss in reflectivity was experienced later. No durability or appearance problems were noted. Locations included in the evaluation were low-volume roadways, but this material has the potential for use on higher-volume asphaltic concrete pavements. Unless reflectivity characteristics are improved, its use should be limited to lighted roadways or roadways where it is supplemented with snowplowable markers. The typical price per linear foot for this material for large installations would enhance its use on high-volume roadways but limit its use on low-volume roadways.

## ALKYD-RESIN EXTRUDED THERMOPLASTIC

Small-scale installations have indicated high initial reflectivity without the loss in reflectivity experienced on the hydrocarbon-resin material. No durability or appearance problems were noted on asphaltic surfaces, but a durability problem related to loss of adhesion has been noted on portland cement concrete pavement.

## 3M STAMARK TAPE

This was the most expensive of all materials evaluated. While there were no durability or appearance problems, reflectivity decreased dramatically. Its cost and poor reflectivity would limit its use to high-volume lighted roadways. The lower price of extruded thermoplastics would probably render use of expensive preformed tapes as lane delineation not cost-effective.

### 3M BISYMMETRIC TAPE

This tape had the highest initial reflectivity of all materials tested. The reflectivity decreased dramatically after two years on a relatively high-volume street. The durability and appearance of this tape were satisfactory. The cost of this tape was substantially less than the Stamark-type tapes and use may be warranted on low- to moderate-volume streets having no lighting.

### EPOFLEX

The EPOFLEX installation inspected in Indiana suffered significant durability problems after less than one year in service. Problems were experienced in several states. A test installation using the a modified material was placed in October 1985 and has performed relatively well for a six-month period. Durability problems related to loss of adhesion have been noted. Further evaluation will continue as part of the Demonstration Project.

### SOLVENT EPOXY

The installation inspected had a complete loss of beads within a few weeks after placement. This would probably be related to either a problem with application or formulation. This material has been used successfully in other states, but additional testing would be necessary before it could be used in Kentucky.

### CHLORINATED RUBBER AND ALKYD TRAFFIC PAINTS

These paints are substantially less expensive than the more durable markings. They provide adequate reflectivity and durability for varying periods based on traffic volumes. In most rural areas, a service life of one year is provided. At high-volume locations, these paints must be restriped at least once per year and should be restriped more than once a year in many instances to maintain adequate reflectivity. Their appearance is very good, having bright white and yellow colors.

## IMPLEMENTATION

Based on current data, expanded use is warranted for 1) polyester paint on lower-volume asphaltic concrete surfaces, 2) extruded thermoplastic on higher-volume asphaltic concrete surfaces having lighting or snowplowable markers, and 3) extruded thermoplastic on open-graded asphaltic concrete. As shown in Table 3, a very high percentage of state-maintained highways have low traffic volumes; therefore, polyester paint could be used. Almost 80 percent of the total mileage included on the statewide roadway volume file has an ADT under 2,500. Use of either polyester paint or extruded thermoplastic would involve contracting for the work since the Kentucky Transportation Cabinet does not have the necessary equipment. The data in Table 3 show that over 90 percent of Kentucky's highways are surfaced with bituminous concrete. The use of portland cement concrete pavement increases dramatically for routes having ADT's exceeding 10,000. These higher-volume roadways are where extruded thermoplastic would be cost-effective, so the effectiveness of thermoplastics on portland cement concrete pavements should receive further investigation.

The high cost of tapes, especially Stamark-type tapes, precludes widespread use. Furthermore, the Stamark tape could be used only where the roadway is lighted or has snowplowable markers in place. No further use of the 100-percent solid epoxy, EPOFLEX, or solvent epoxy paint is recommended until such time that additional testing proves problems have been resolved.

There is a need to monitor the large installations of polyester paint and hydrocarbon-resin and alkyd-resin extruded thermoplastics scheduled to be placed by contract in 1986. There is also a need to monitor and evaluate 1) any new installation of previously tested materials, such as 100-percent solid epoxy, that have been altered since placed as part of this evaluation and 2) installations of marking materials not previously tested, such as water-based traffic paint.

TABLE 1. TYPICAL PRICES OF MARKING MATERIALS (MATERIALS AND INSTALLATION)

| MATERIAL | COST (CENTS PER LINEAR FOOT FOR 4-INCH LINE) |
|---|---|
| 100-Percent Solid Epoxy Paint | 20 - 30 |
| Polyester Paint | 7 - 12 |
| Extruded Thermoplastic | 25 - 35 |
| 3M Stamark Tape | 80 - 110 |
| 3M Bisymmetric Tape | 50 - 60 |
| EPOFLEX | 15 - 20 |
| Solvent Epoxy Paint | 10 - 15 |
| Chlorinated Rubber Traffic Paint | 3 - 5 |
| Alkyd Traffic Paint | 3 - 5 |

TABLE 2. SUMMARY OF PORTABLE RETROREFLECTOMETER (PRR) DATA

| | | PRR MEASUREMENT | | | | |
|---|---|---|---|---|---|---|
| MATERIAL | COLOR | 1982 | 1983 | 1984 | 1985 | 1986 |
| 100-Percent Solid Epoxy Paint | White | 290 | 190 | 150 | *** | *** |
| - Lexington | Yellow | 230 | 140 | 140 | *** | *** |
| - Louisville | White | 290 | 170 | 160 | 160 | *** |
| | Yellow | 240 | 160 | 140 | 140 | *** |
| - Northern Kentucky | White | 270 | 180 | 170 | *** | *** |
| | Yellow | 220 | 170 | 160 | *** | *** |
| Polyester Paint | White | 250 | 150 | 170* | 160* | 140* |
| | Yellow | 190 | 90 | 100* | 120* | 110* |
| Extruded Thermoplastic (Hydrocarbon) | White | 290 | 230 | 160 | 140 | 130 |
| | Yellow | 200 | 80 | 70 | 100 | 90 |
| Extruded Thermoplastic (Alkyd) | White | ** | ** | ** | 380 | 300 |
| | Yellow | ** | ** | ** | 210 | 190 |
| 3M Stamark Tape | White | 360 | 160 | 130 | 120 | 120 |
| | Yellow | 280 | 120 | 110 | 90 | 90 |
| 3M Bisymmetric Tape | White | 550 | 200 | 130 | *** | *** |
| EPOFLEX -- Indiana | White | ** | 180 | 100 | *** | *** |
| | Yellow | ** | 100 | 80 | *** | *** |
| EPOFLEX -- Jefferson County | White | ** | ** | ** | 240 | 180 |
| | Yellow | ** | ** | ** | 140 | 130 |
| Solvent Epoxy Paint -- Indiana | Yellow | ** | 70 | ** | ** | ** |
| Chlorinated Rubber Traffic Paint | White | 210 | 100 | ** | ** | ** |
| | Yellow | 180 | 80 | ** | ** | ** |
| Alkyd Traffic Paint | White | ** | ** | ** | 160 | 130 |
| | Yellow | ** | ** | ** | 110 | 90 |

* Measurements increased as a result of additional paint applications.
** No data for this time period.
*** Material painted over.

TABLE 3. STATEWIDE MILEAGE SUMMARY BY ADT AND SURFACE TYPE

| ADT RANGE | TOTAL MILEAGE | PERCENT OF TOTAL | PERCENT HAVING GIVEN SURFACE TYPE | | |
|---|---|---|---|---|---|
| | | | BITUMINOUS | PC CONCRETE | OTHER |
| Under 500 | 10,459 | 41.7 | 92 | 0 | 8 |
| 500 - 999 | 4,389 | 17.5 | 98 | 0 | 2 |
| 1,000 - 2,499 | 4,587 | 18.3 | 99 | 1 | 0 |
| 2,500 - 4,999 | 2,635 | 10.5 | 89 | 11 | 0 |
| 5,000 - 9,999 | 1,584 | 6.3 | 83 | 17 | 0 |
| 10,000 - 19,999 | 846 | 3.4 | 66 | 33 | 1 |
| 20,000 or more | 564 | 2.3 | 36 | 64 | 0 |

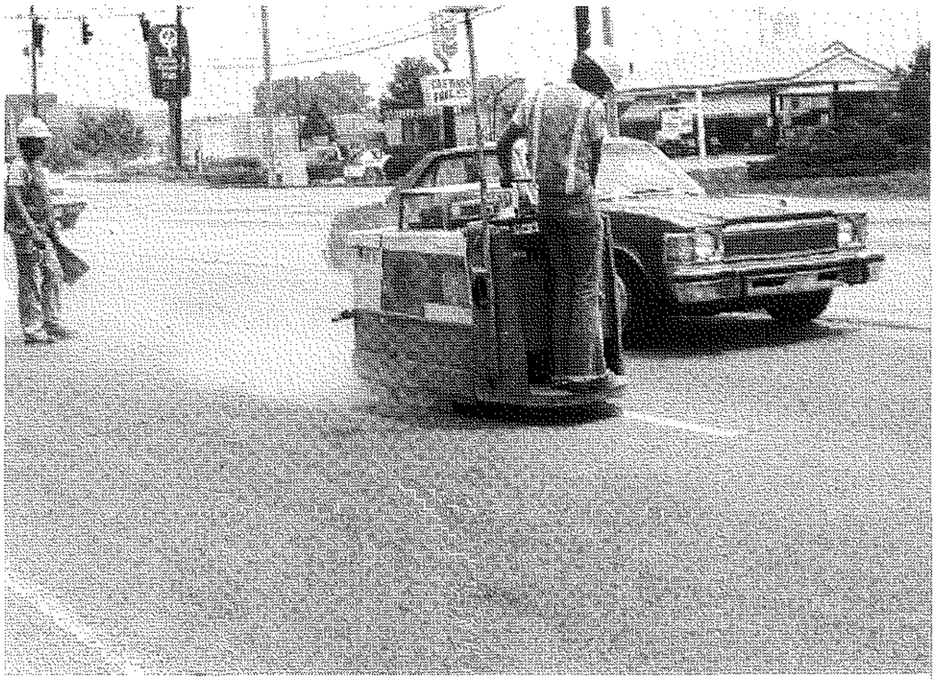

Figure 1. Removing Old Paint Stripe.

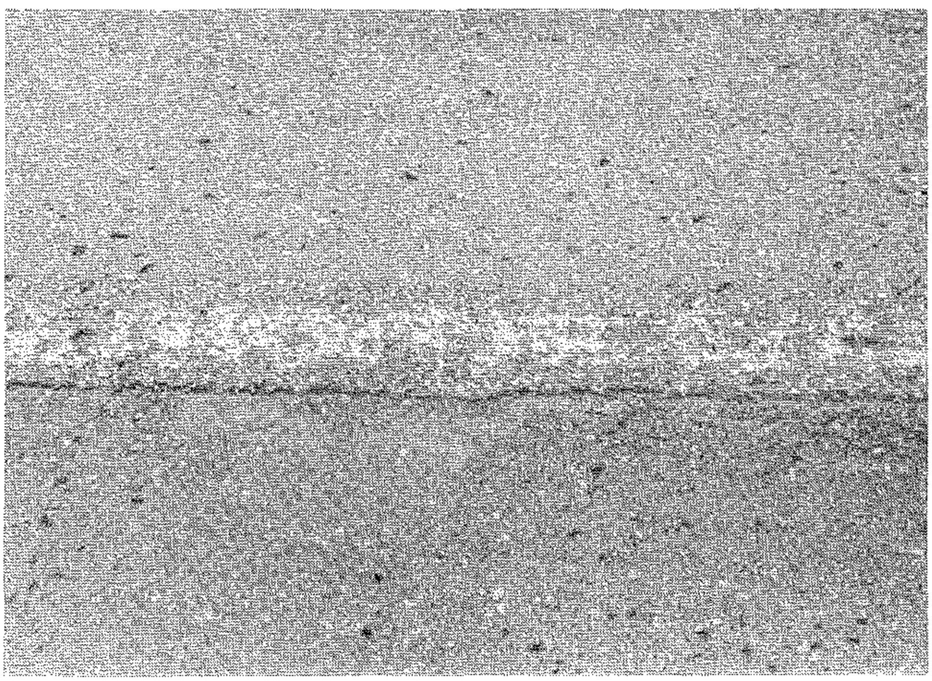

Figure 2. Pavement Condition after Grinding.

Figure 3. Groove due to Excessive Grinding.

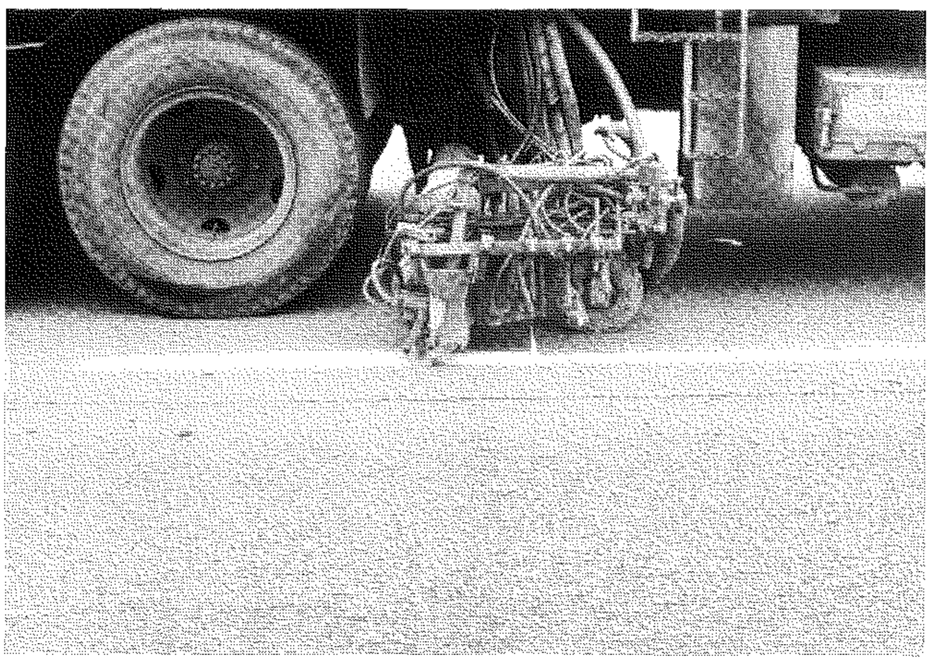

Figure 4. Application of Solid Epoxy Using Free-Fall Bead Dispenser.

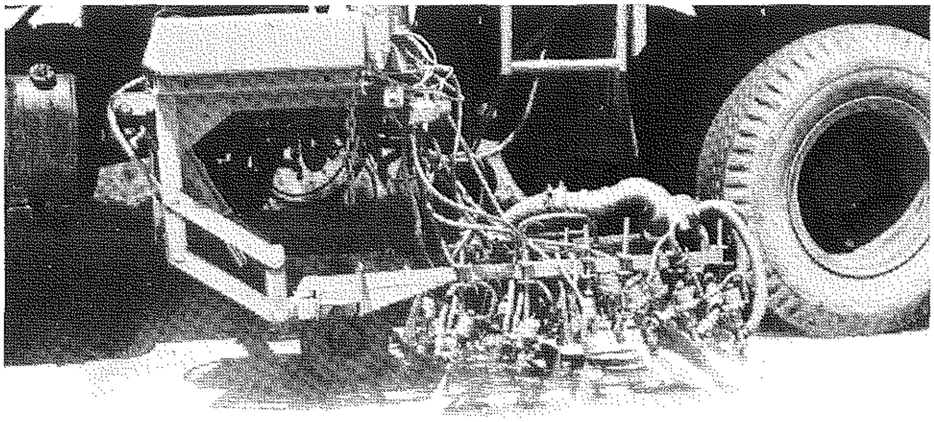

Figure 5. Application of Solid Epoxy with Beads Applied by Pressure through Several Bead Guns.

Figure 6. Reflectivity of Solid Epoxy after a Few Months in Service (KY 17 in Kenton County).

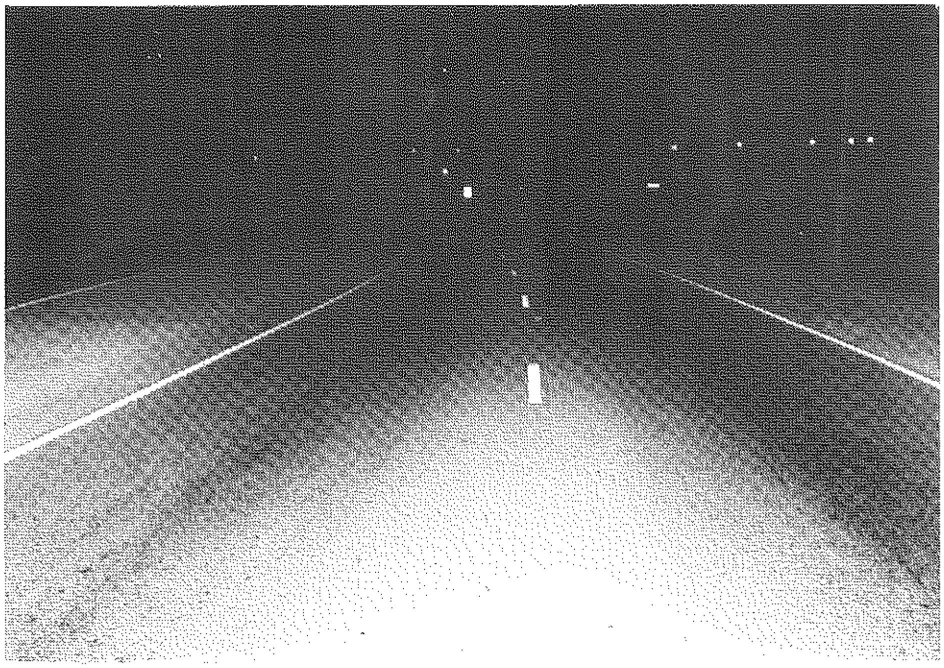

Figure 7. Reflectivity of Solid Epoxy after About Two Years in Service (KY 17 in Kenton County).

Figure 8. Reflectivity of Solid Epoxy after About Four Years in Service (KY 17 in Kenton County).

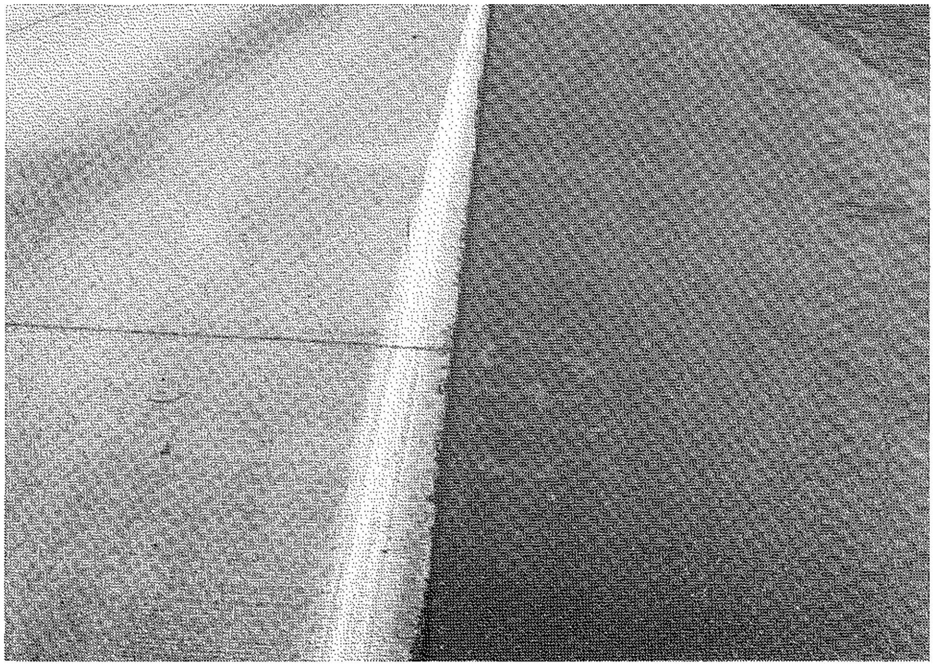

Figure 9. Beginning of Brown Discoloration of Solid Epoxy Stripe.

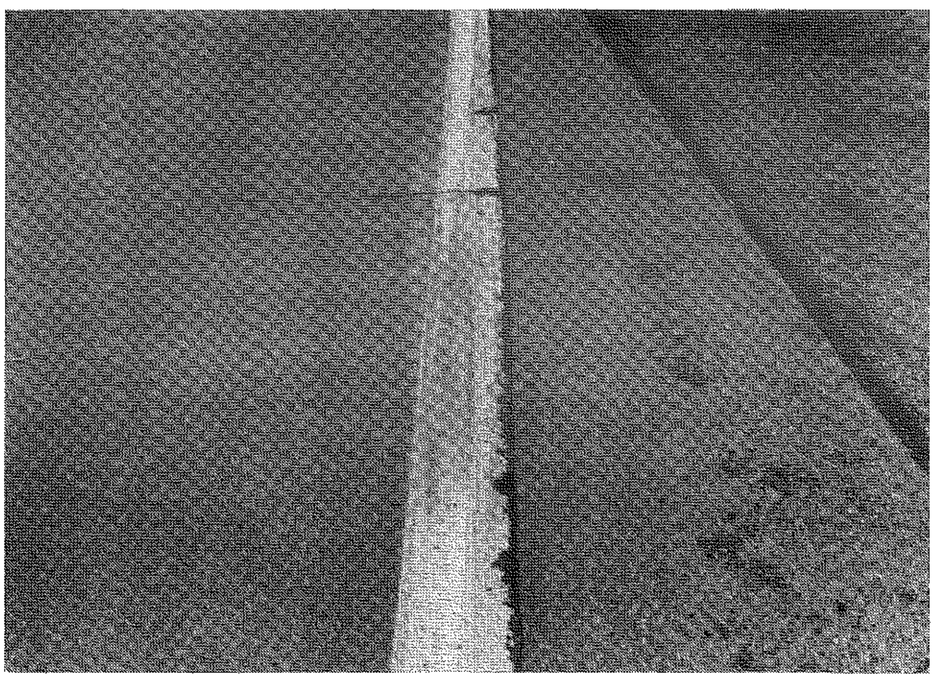

Figure 10. Very Dark Discoloration of Solid Epoxy Stripe.

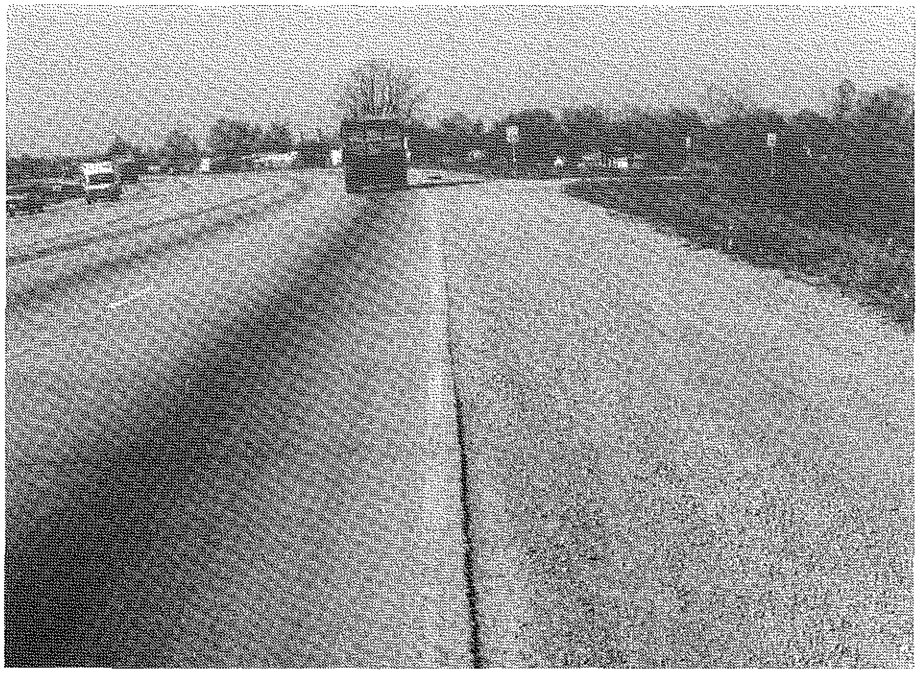

Figure 11. Wear on Solid Epoxy Edge Line after About 18 Months Service (KY 18 in Boone County).

Figure 12. Wear on Solid Epoxy Centerline after About One Year in Service (KY 1998 in Campbell County).

Figure 13. Loss of Reflectivity Resulting from Wear of Solid Epoxy Centerline (KY 1998 in Campbell County).

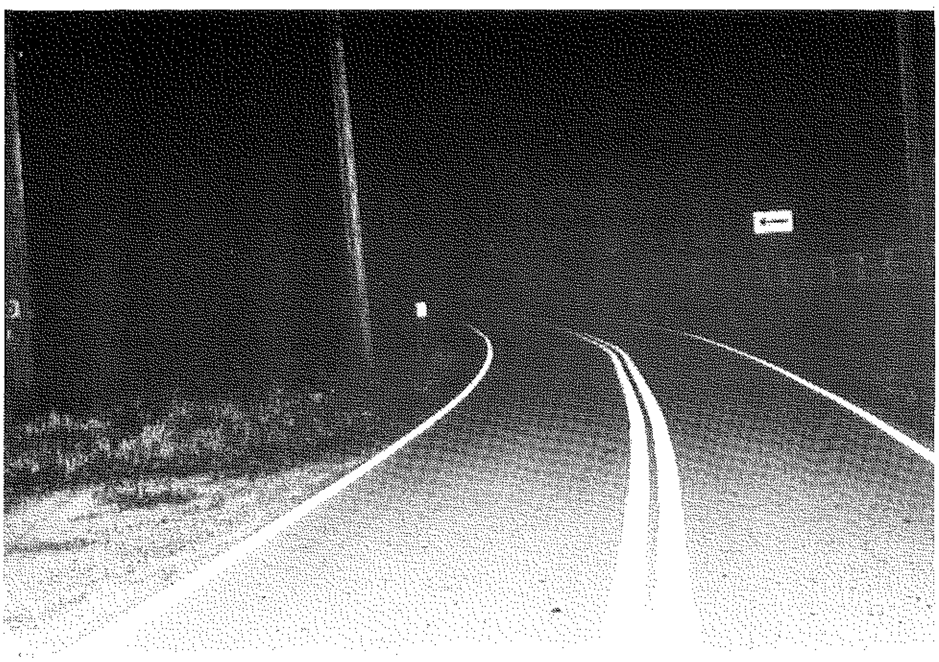

Figure 14. Reflectivity of Solid Epoxy Line Immediately after Installation (KY 1968 in Fayette County).

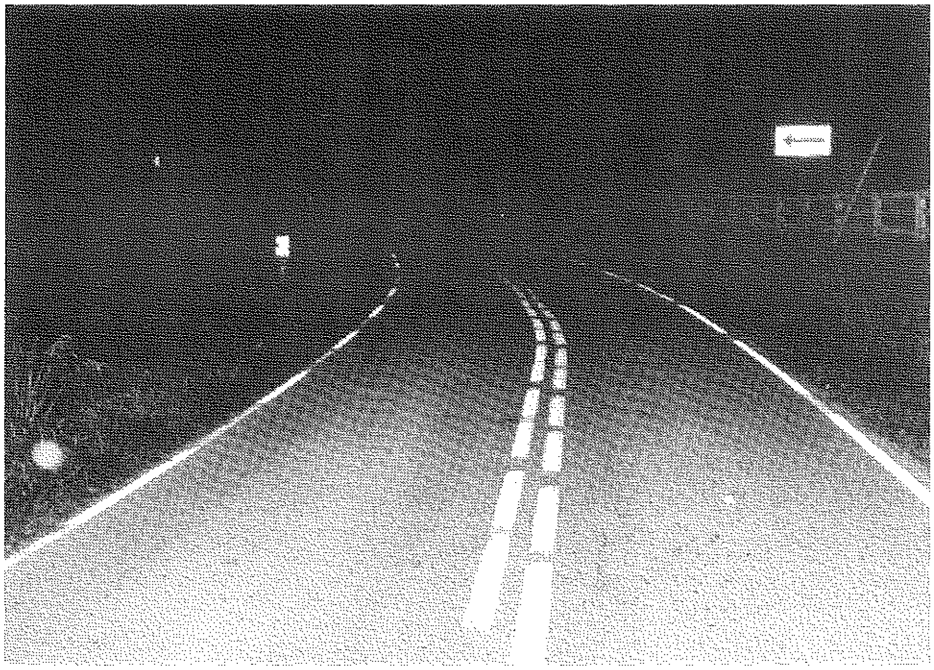

Figure 15. Loss of Reflectivity after About Two Years in Service Resulting from Wear to Solid Epoxy Line (KY 1968 in Fayette County).

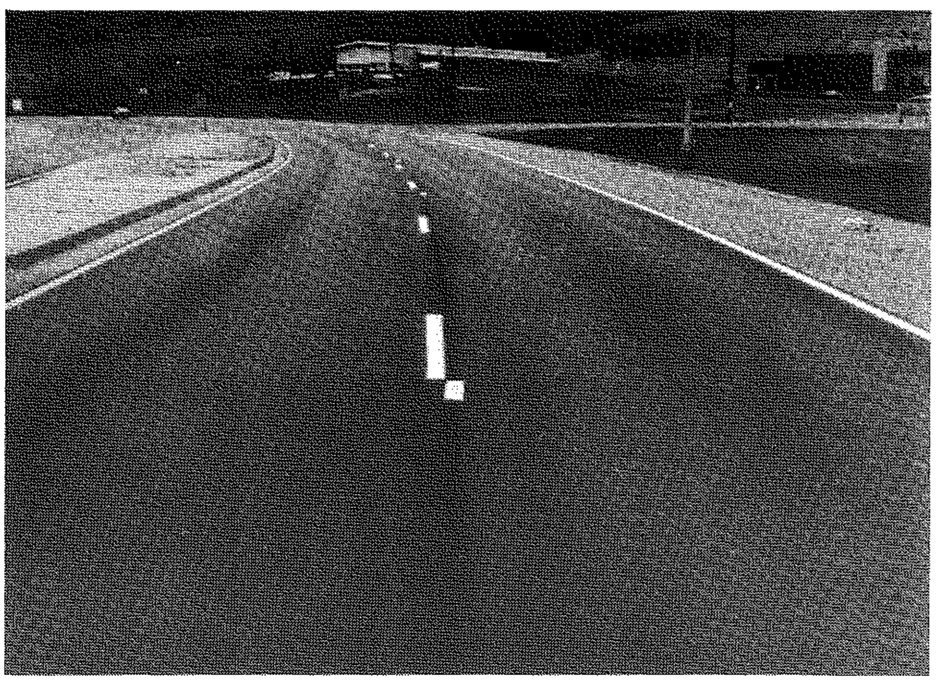

Figure 16. Appearance of Solid Epoxy Line Immediately after Placement (KY 17 in Kenton County).

Figure 17. Appearance of Yellow Solid Epoxy Line after Two Years in Service (KY 1974 in Fayette County).

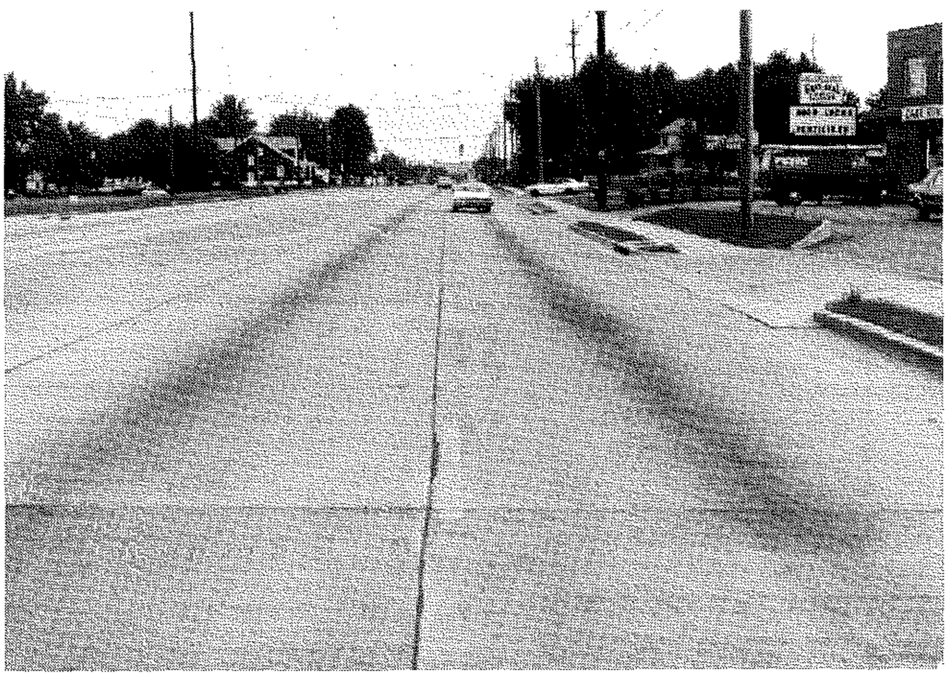

Figure 18. Appearance of White Solid Epoxy Line on Concrete Pavement after Two Years in Service (KY 1934 in Jefferson County).

Figure 19. Placement of Polyester Paint.

Figure 20. Reflectivity of Polyester Paint a Few Months after Placement (Maryman Road in Jefferson County).

Figure 21. Reflectivity of Polyester Paint almost Four Years after Placement of Edge Line and Three Years after Last Placement of Centerline (Maryman Road in Jefferson County).

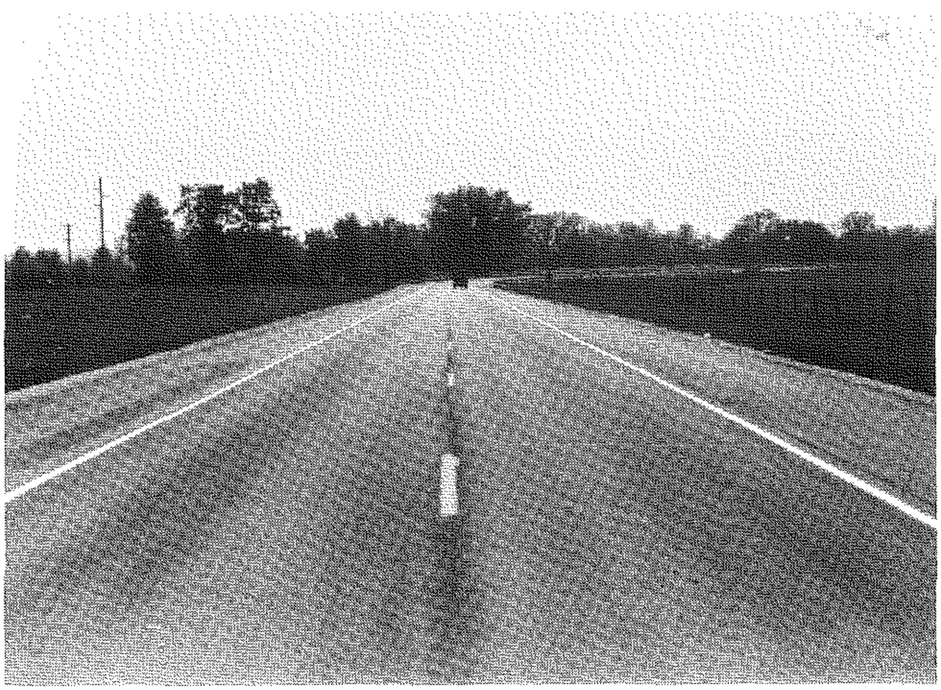

Figure 22. New Polyester Paint Installation (Deering Road in Jefferson County).

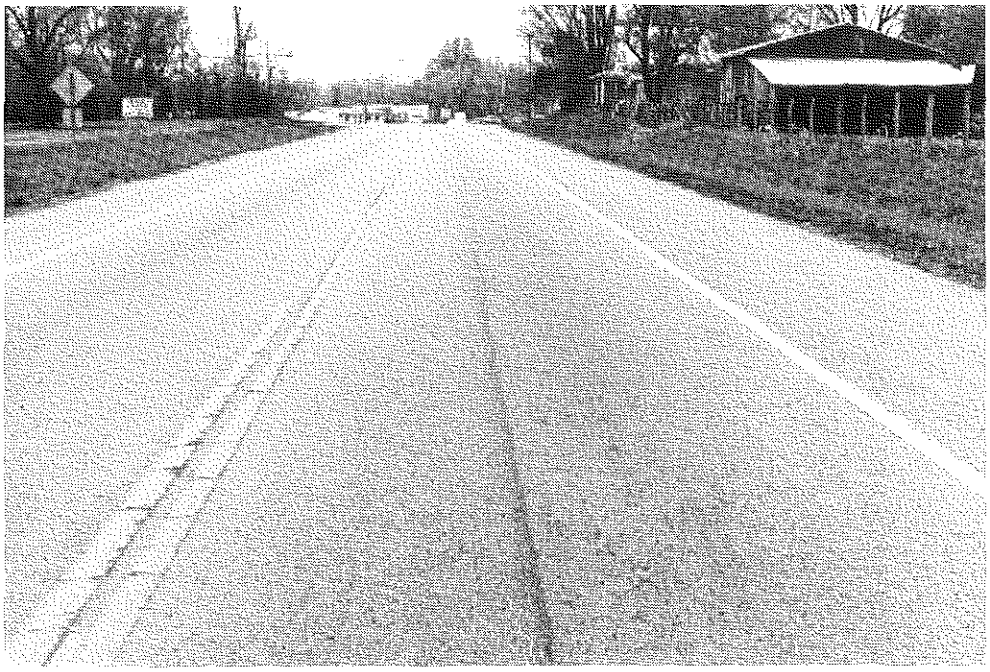

Figure 23. Polyester Paint Installation Fours Years after First Placement with Two Additional Installations (Deering Road in Jefferson County).

Figure 24. Lack of Adhexive of Polyster Paint Placed on Old Polyester Paint Line.

Figure 25. Dark Color Resulting from Dirt Contamination of Polyester Line.

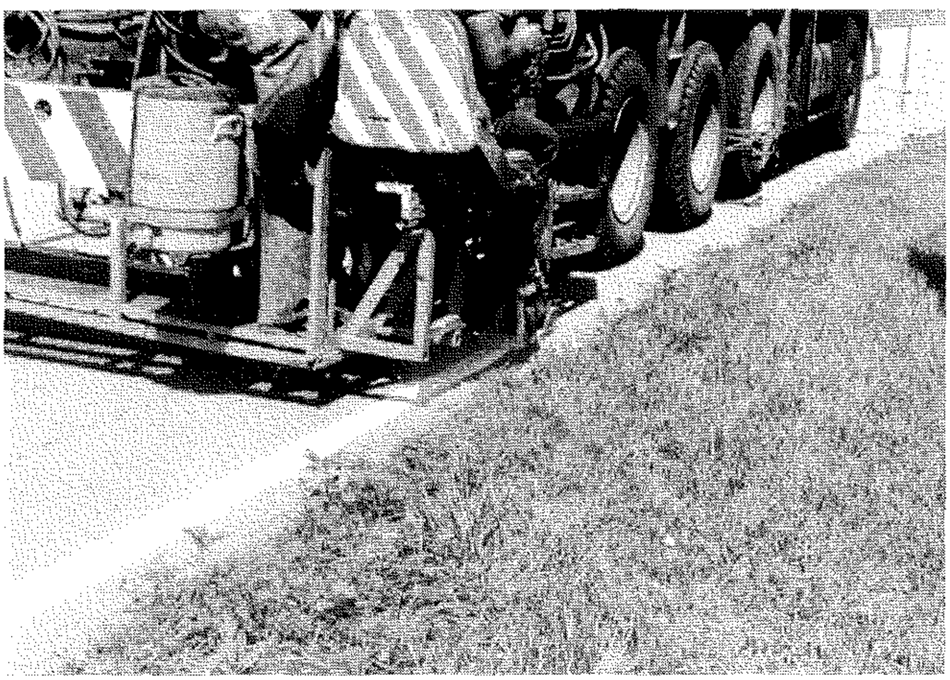

Figure 26. Placement of Hydrocarbon-Resin Extruded Thermoplastic Line.

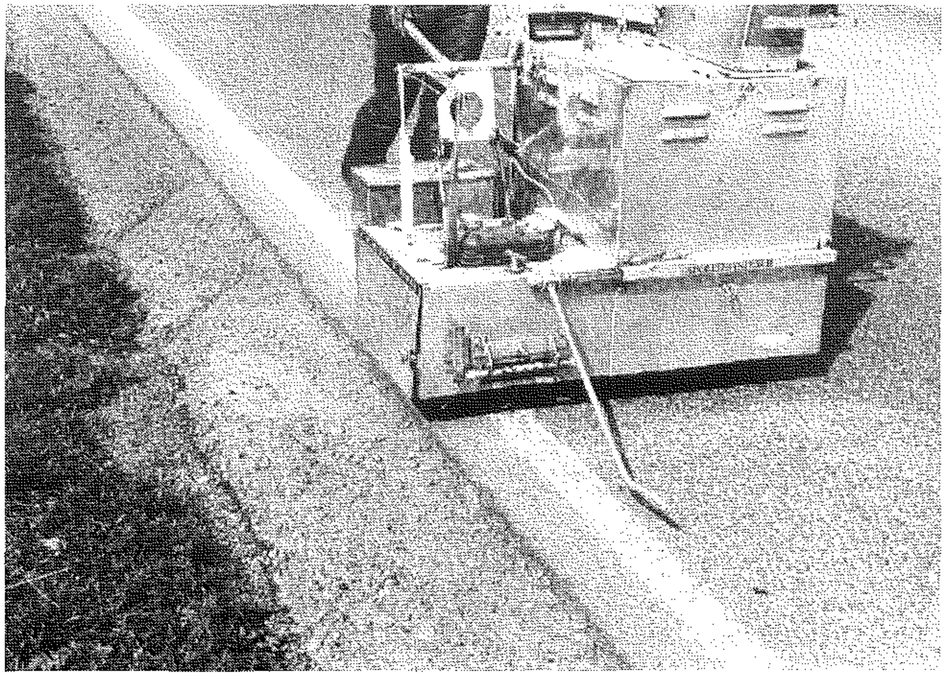

Figure 27. Placement of Alkyd-Resin Extruded Thermoplastic Line.

Figure 28. Reflectivity of Hydrocarbon-Resin Extruded Thermoplastic Line A few Months after Placement (US 62 in Harrison County).

Figure 29. Reflectivity of Hydrocarbon-Resin Extruded Thermoplastic Line after about Two Years in Service (US 62 in Harrison County).

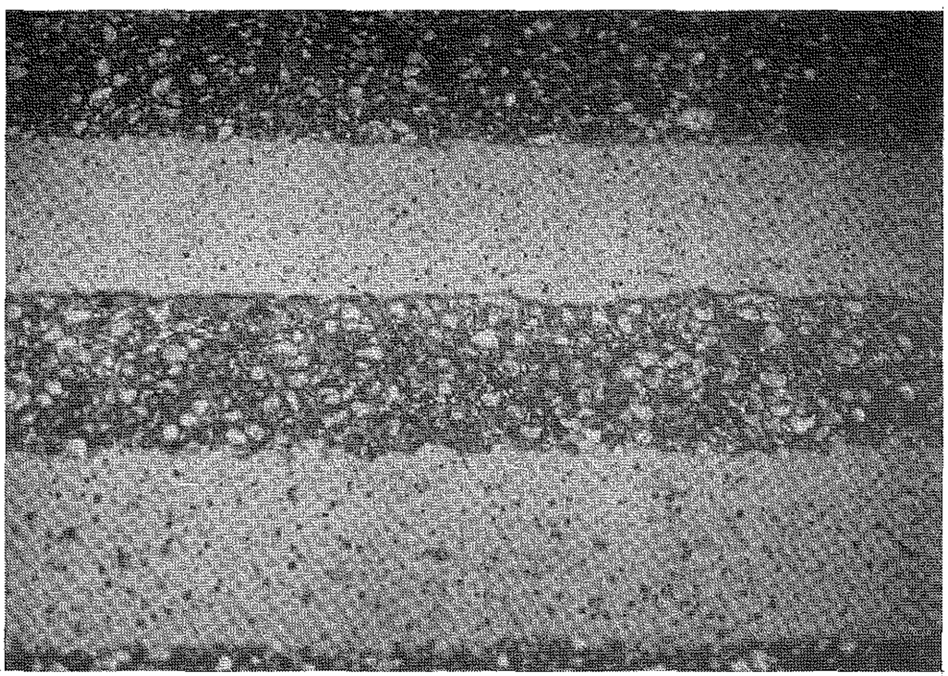

Figure 30. Small Holes in Surface of Yellow Hydrocarbon-Resin Extruded Thermoplastic Line.

Figure 31. Bond Problem between Portland Cement Concrete Pavement and Hydroncarbon-Resin Extruded Thermoplastic (US 68 in Trigg County).

Figure 32. Hydrocarbon-Resin Extruded Thermoplastic Installation after Three Years in Service (KY 94 in Calloway County).

Figure 33. New Installation of Alkyd-Resin Extruded Thermoplastic (North Limestone Street in Lexington).

Figure 34. Alkyd-Resin Extruded Thermoplastic Installation after About One Year in Service (North Limestone Street in Lexington).

Figure 35. Nighttime Reflectivity of New Installation of Alkyd-Resin Extruded Thermoplastic (Lane Lines) (Harrodsburg Road in Lexington).

Figure 36. Nighttime Reflectivity of Alkyd-Resin Extruded Thermoplastic after About One Year in Service as Lane Lines (Harrodsburg Road in Lexington).

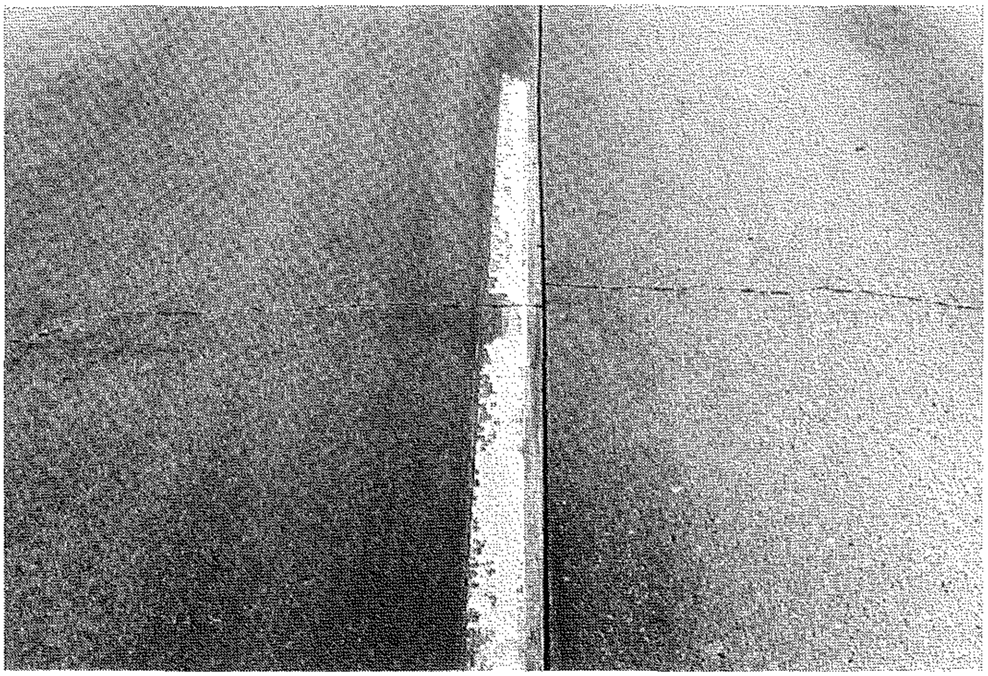

Figure 37. Durability Problem of Alkyd-Resin Extruded Thermoplastic on Portland Cement Concrete (US 68 [Harrodsburg Road] in Lexington).

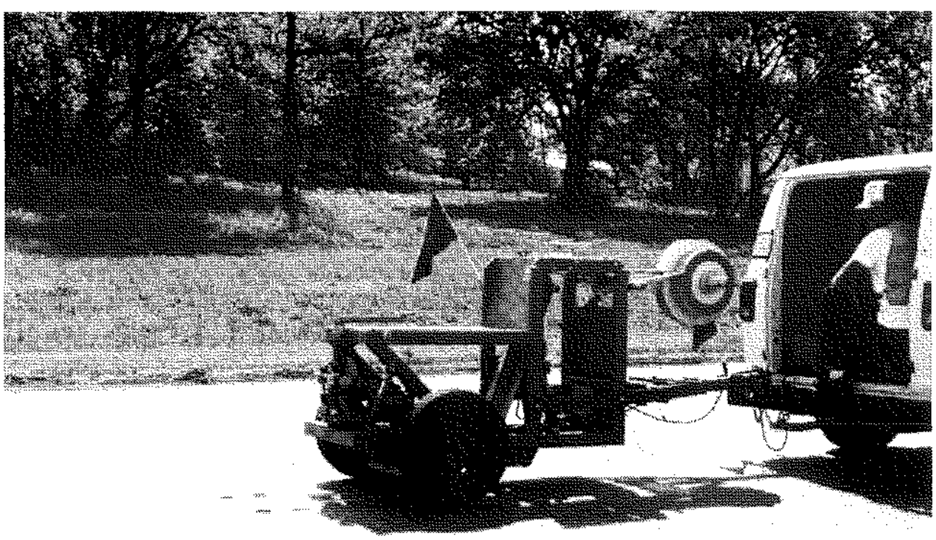

Figure 38. Placement of 3M Stamark Tape.

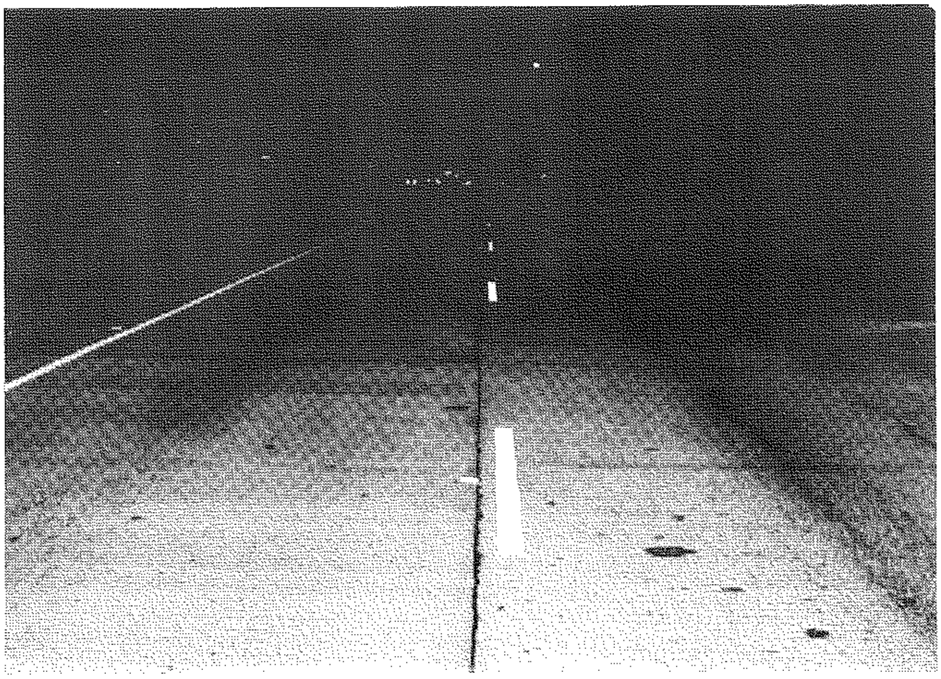

Figure 39. Reflectivity of Stamark Tape a Few Weeks after Placement (Hikes Lane in Jefferson County).

Figure 40. Reflectvity of Stamark Tape About Two Years after placement (Hikes Lane in Jefferson County).

Figure 41. Comparison of Reflectivity of Stamark Tape (White Lane Line and Yellow [Left] Edge Line) with Polyester Paint (White Edge Line) after About Two Years in Service (Fegenbush Lane in Jefferson County).

Figure 42. Appearance of Stamark Tape after About Four Years in Service (Hikes Lane in Jefferson County).

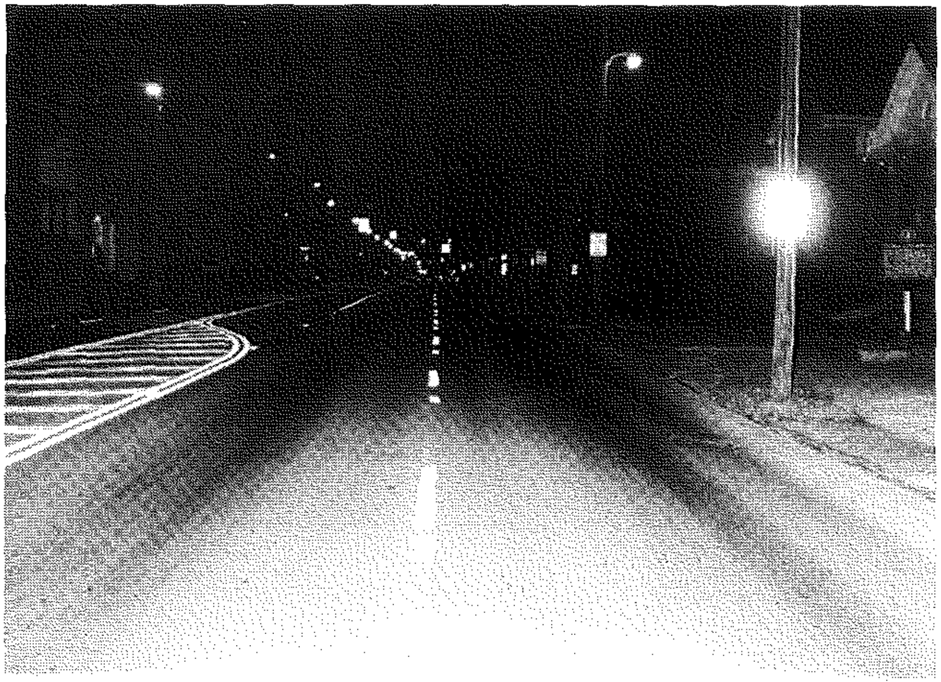

Figure 43. Reflectivity of 3M Bisymmetric Tape (Lane Lines) a Few Weeks after Placement (North Broadway in Lexington).

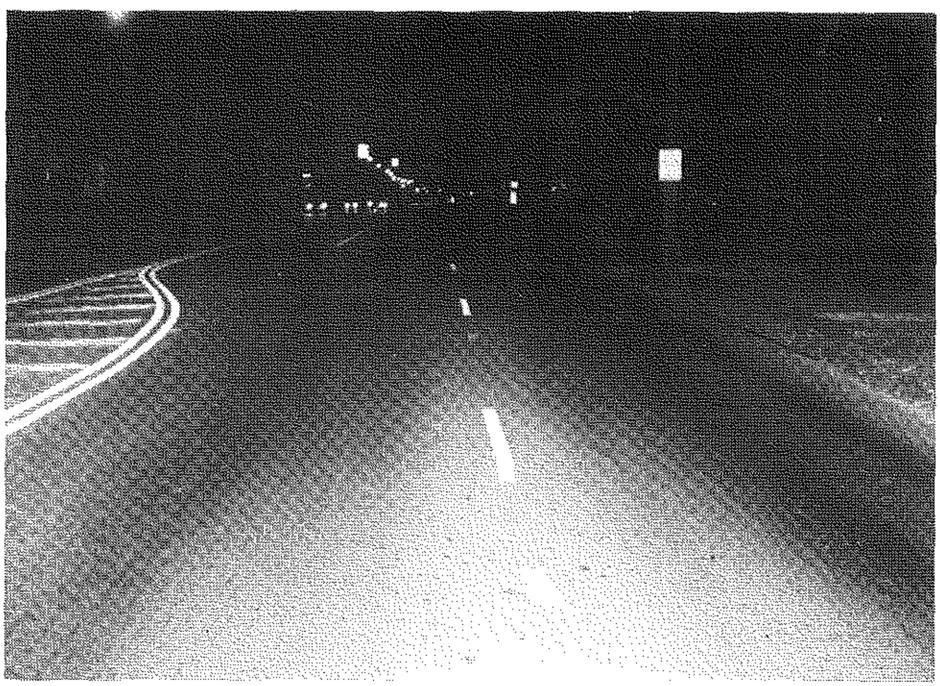

Figure 44. Reflectivity of 3M Bisymmetric Tape (Lane Lines) after About Two Years Service (North Broadway in Lexington).

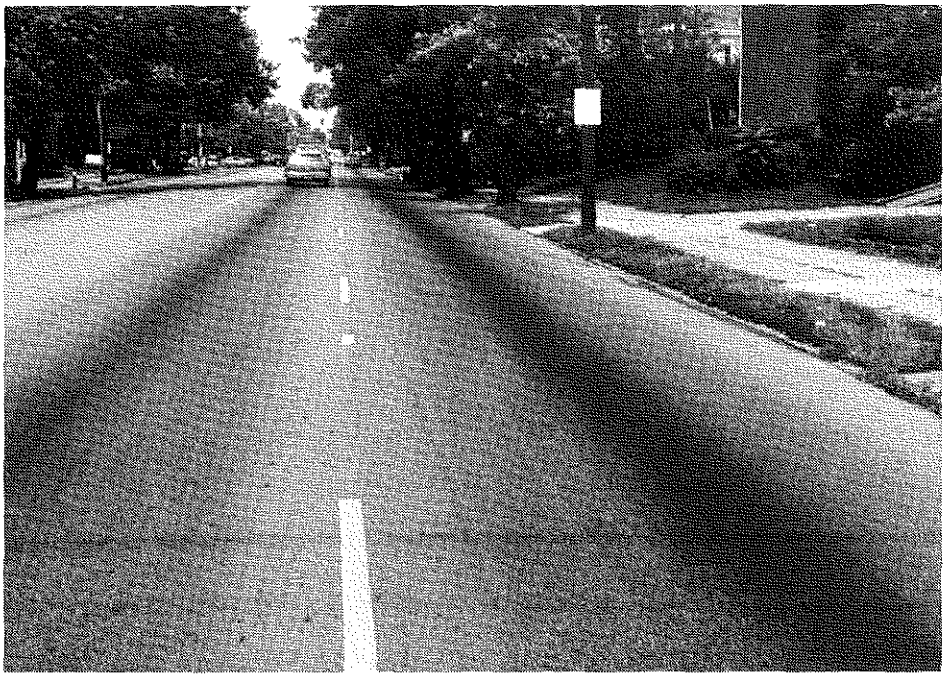

Figure 45. Appearance of 3M Bisymmetric Tape after About Two Years in Service (North Broadway in Lexington).

Figure 46. Equipment Used in Place EPOFLEX.

Figure 47. Durability Problem with EPOFLEX after about One Year in Service (State Route 135 in Harrison County, Indiana).

Figure 48. EPOFLEX Installation after a Few Days in Service (Jefferson Freeway in Jefferson County).

Figure 49. Reflectivity of EPOFLEX Installation after a Few Days in Service (Jefferson Freeway in Jefferson County).

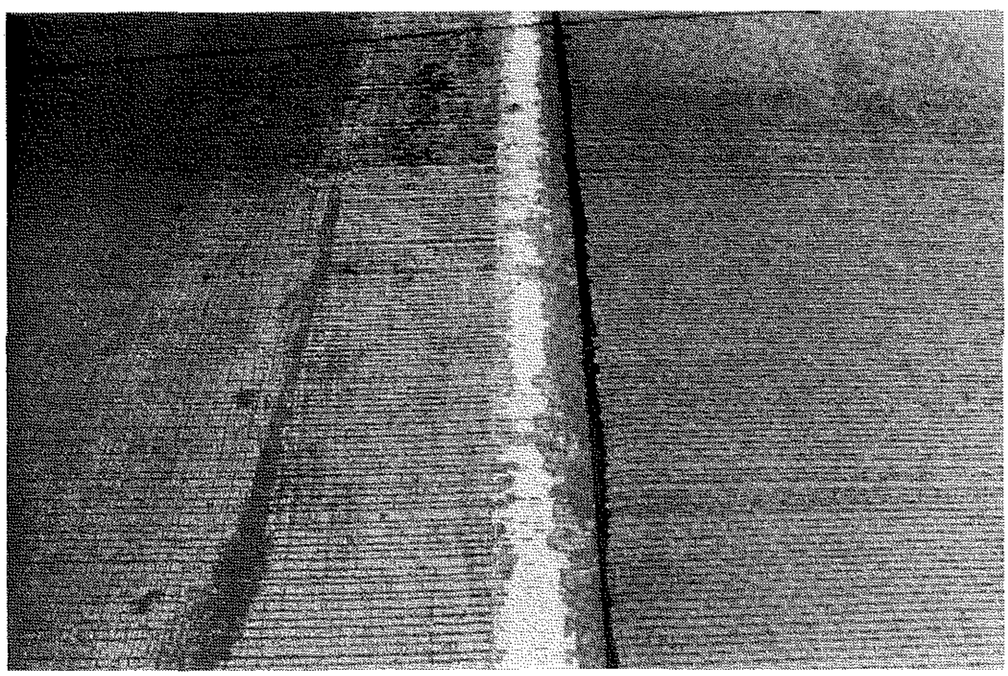

Figure 50. Durability Problem of EPOFLEX Installation (Jefferson Freeway in Jefferson County).

Figure 51. Placement of Chlorinated Rubber Traffic Paint.

Figure 52. Reflectivity of Chlorinated Rubber Traffic Paint a Few Months after Placement (US 127 in Mercer County).

Figure 53. Reflectivity of Chlorinated Rubber Traffic Paint after About One Year in Service (US 27 in Fayette County).